Remote, Non-Contact and Continuous Extraction of Multiple Peoples' Autonomic Nervous System Indices from One Fish-Eye Camera

Makoto Yoshizawa, Norihiro Sugita*, Akira Tanaka, Noriyasu Homma***, Emi Yuda****, Tomoyuki Yambe*******

Center for Promotion of Innovation Strategy, Tohoku University, Sendai 980-0845, Japan
* Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan
** Faculty of Symbiotic Systems Science, Fukushima University, Fukushima 960-1296, Japan
*** Graduate School of Medicine, Tohoku University, Sendai 980-8575, Japan
**** Center for Data-Driven Science and Artificial Intelligence, Tohoku University, Sendai 980-8576, Japan
***** Institute of Development, Aging and Cancer, Tohoku University, Sendai 980-8575, Japan
Keywords: Video pulse, Remote and non-contact measurement, Autonomic nervous system indices, Fish-eye camera, *COVID-19*.

ABSTRACT

An image processing system using a fish-eye camera has been developed to continuously record multiple persons' autonomic nervous system indices by automatically measuring and analyzing their pulse waves.

1 INTRODUCTION

To cope with the new life style of With-After COVID-19, the authors have been developing a non-contact and remote health monitoring cloud system using video images shot by ordinary video cameras of clients' personal computers or smart phones including camera applications with MJPG compression (https://mirror-magical.net) [1].

Unlike wearable sensors such as watch- or wristband-type sensors, this system can measure pulse waves (video-plethysmograms; VPG) from body video images and obtain autonomic nervous system indices without wearing any sensors. However, this system requires us to operate a Web browser consciously. This interferes with continuous measurement which is essential for daily health management.

In this study, we have developed an image processing system using a fish-eye camera to continuously record multiple persons' autonomic nervous system indices by automatically measuring and analyzing their VPGs. If this system is placed on a dining table, etc., it will be able to keep recording family members' health-related information on a daily basis without any conscious operation.

2 METHODS

2.1 Transformation from Fish-Eye Image to Equirectangular Image

A fish-eye camera (Lysong; PANO VIEW) was used to shoot fish-eye movie images placed on a position surrounded by multiple persons, as shown in Figs.1a) and b). It is a matter of course that VPGs can be obtained only from the human bodies, especially faces. However, an intact fish-eye image is too distorted to detect human faces. Therefore, it is necessary to transform the fish-eye Image to the equirectangular Image as follows:

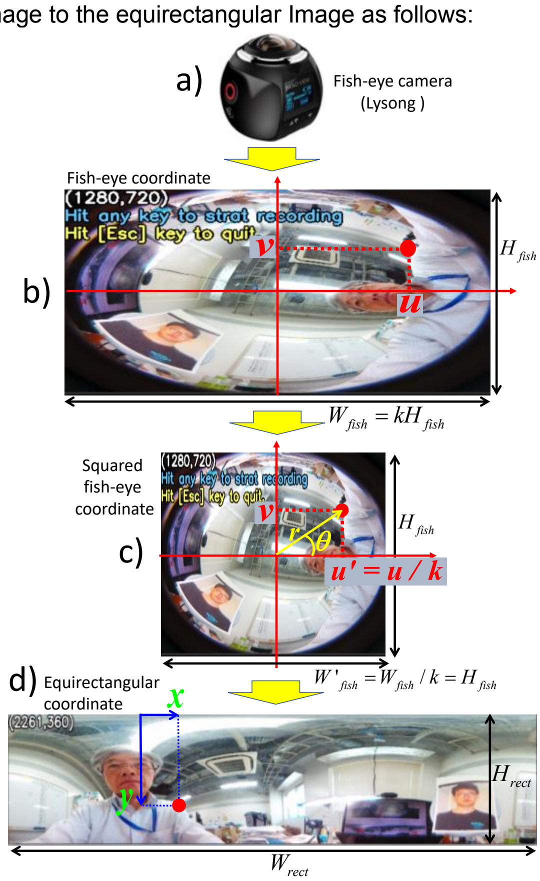

Fig. 1 Transformation from a fish-eye image to an equirectangular image.

1) Take an elliptical fish-eye image with the fish-eye camera. In the case of this camera, its size and aspect ratio are $W_{fish} : H_{fish} = 1280 : 720$ and $k : 1 = 1.78 : 1$, respectively.
2) Let (u, v) denote the coordinate of Fig.1b), and

$(u', v) = (u/k, v)$ denote that of Fig.1c), which is deformed from Fig.1b) to have the squared shape.

3) Get the equirectangular image shown in Fig.1d) whose size and coordinate are $(W_{rect}, H_{rect}) = (2261, 360)$ and (x, y), respectively. These variables satisfy the following equations:

$$\begin{cases} W_{rect} = \pi H_{fish} \\ H_{rect} = H_{fish}/2 \end{cases} \quad (1)$$

$$\begin{cases} r = y \\ \theta = 2\pi x / W_{rect} = 2x / H_{fish} \end{cases} \quad (2)$$

$$\begin{cases} u = k\left(H_{fish}/2 + y\sin\theta\right) \\ v = H_{fish}/2 + y\cos\theta \end{cases} \quad (3)$$

2.2 Automatic Detection and Stabilization of Region of Interest (ROI) for Extraction of VPGs

Figure 2b) is an example of the equirectangular image transformed from the original fish-eye image of Fig.2a), in which there are four people. The Viola-Jones algorithm is applied to the equirectangular image to detect the position of the face and eyes of each person, and the Lucas-Kanade method is used to stabilize each area against the movement of each face. The rectangular areas (region of interest; ROI) of the cheek and forehead are automatically set to extract the corresponding VPGs.

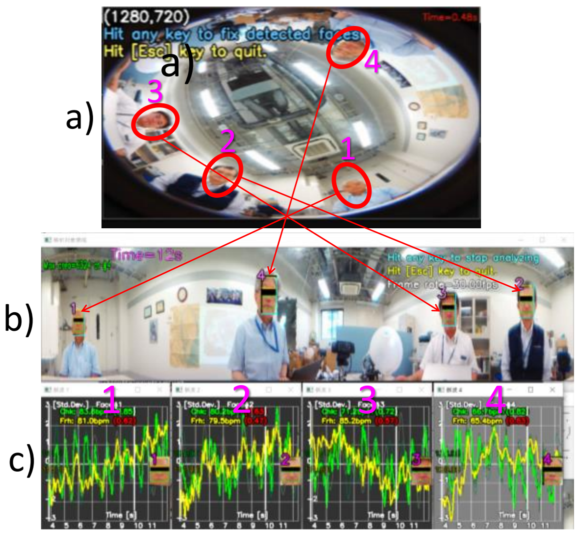

Fig.2 Detection of ROIs and extraction of VPGs.

Since hemoglobin in blood absorbs the green component of ambient light well, the VPGs can be extracted from these areas by averaging the intensity of the green signal of each pixel.

2.3 Extraction of Autonomic Nervous System Indices

Foot-to-foot intervals (FFI [ms]) are determined based on the time point giving the local minimum of the VPG to obtain the heart rate variability, and its frequency components are calculated to obtain autonomic nervous system indices such as $CVRR$ [%] of FFI (para-sympathetic nervous index) and LF/HF (the balance index between sympathetic and para-sympathetic nervous activities), and so on [2]. These indices are calculated in a data window with the length of 25 s which shifts beat by beat.

The VPGs are very sensitive to body movements and the variation in intensity of ambient light. To judge whether the measured VPGs are valid or not, the signal to noise ratio (SNR) defined as the ratio of heartbeat frequency components around 1 Hz to the sum of those and higher frequency components is recorded beat by beat.

The above beat-to-beat time series data are recorded for a data window with the length of 180 s which can save every preassigned period.

3 RESULTS AND DISCUSSION

The proposed system was constructed with C++ and OpenCV 4.5.0 on Windows 10 in a computer (VAIO pro PF). The system can operate at the frame rate of 30 fps. In the case of Fig.2b), as shown in https://mirror-magical.net/English/Fish-eye.webm, each person's VPGs were obtained as shown in Fig.2c), in which the green and yellow curves correspond to the cheek and forehead parts, respectively.

Table 1 shows a comparison of the *SNR* between the fish-eye camera and an ordinary Web camera for two kinds of ROI assignment methods for 30 s long movie data obtained from a person. This suggests that the fish-eye camera has a room for improving the *SNR*, for example, by use of much higher resolution cameras.

Table 1 Comparison of *SNR*.

ROI assignment method	ROI	Fish-eye camera (Lysong; PANO VIEW)	Web camera (Logicool ; C922)
Automatic face detection	Cheek	0.69	0.92
	Forehead	0.44	0.89
Manually by mouse	Cheek	0.85	0.97
	Forehead	0.81	0.96

4 CONCLUSIONS

The proposed system has a possibility to apply to unconscious and automatic family members' health management if a face identification function is added.

ACKNOWLEDGMENT

This work was supported by the COI Stream Project founded by Japanese Ministry of ESSC.

REFERENCES

[1] M. Yoshizawa, N. Sugita, A. Tanaka, *et al*., "A cloud system for extraction of autonomic nervous system indices and blood pressure variabilities from video Images," 27th IDW '20, pp.983-984 (2020)

[2] M. Yoshizawa, N. Sugita, A. Tanaka, *et al.*, "Remote monitoring of autonomic nervous system Indices using video cameras," 4th IEEE GCCE, pp.670–671 (2015).